INTRAVENOUS CARDIAC PACING SYSTEM WITH WIRELESS POWER SUPPLY

Cross-reference to Related Applications

Not Applicable

Statement Regarding Federally Sponsored Research or Development

Not Applicable

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to implantable medical devices which deliver energy to heart tissue to stimulate cardiac contractions, and more particularly to such cardiac pacing devices that are implantable in a vein or artery.

2. Description of the Related Art

[0002] A remedy for people with slowed or disrupted natural heart activity is to implant a cardiac pacing device which is a small electronic apparatus that stimulates the heart to beat at regular rates.

[0003] Typically the pacing device is implanted in the patient's chest and has sensor electrodes that detect electrical impulses associated with in the heart contractions. These sensed impulses are analyzed to determine when irregular cardiac activity occurs, in which event a pulse generator is triggered to produce electrical pulses. Wires carry these pulses to patch-type stimulation electrodes placed adjacent specific cardiac muscles, which when electrically stimulated contract the heart chambers. It is important

that the stimulation electrodes be properly located to produce contraction of the heart chambers.

[0004] Modern cardiac pacing devices vary the stimulation to adapt the heart rate to the patient's level of activity, thereby mimicking the heart's natural activity. The pulse generator modifies that rate by tracking the activity at the sinus node of the heart or by responding to other sensor signals that indicate body motion or respiration rate.

[0005] U.S. Patent No. 6,445,953 describes a cardiac pacemaker that has a pacing device, which can be located outside the patient, to detect irregular or weak cardiac activity. In that event, the pacing device emits a radio frequency signal, that is received by a circuit mounted on a stent implanted in a vein or artery of the patient's heart. Specifically, the radio frequency signal induces a voltage pulse in an antenna on the stent and that pulse is applied across a pair of electrodes on the stent, thereby stimulating adjacent muscles and contracting the heart. Although this cardiac pacing apparatus offered several advantages over other types of pacemakers, it required placement of sensing electrodes on the patient's chest in order for the external pacing device to detect when the heart requires stimulation.

Summary of the Invention

[0006] A cardiac pacing apparatus is provided to artificially stimulate contractions of a heart in an animal. That apparatus includes a power transmitter which periodically transmits a pulse of a radio frequency signal to a vascular electrode-stent that is implanted preferably in a vein or artery the animal.

[0007] The vascular electrode-stent comprises an pickup device, such as a coil of wire for example, for receiving the radio frequency signal and a cardiac signal emitted from the sinus node of the heart. A pacing signal circuit is connected to the pickup device and a pair of electrodes that are in contact with tissue of the animal. The pacing signal circuit has an electrical storage device that is charged by electrical energy from the radio frequency signal. In response to detecting the cardiac signal, the pacing signal circuit applies a stimulation voltage pulse across the pair of electrodes to cause a contraction of the heart.

[0008] In a preferred embodiment of the vascular electrode-stent, the pacing signal circuit includes a discriminator and a pulse circuit. The discriminator is connected to the pickup device and controls charging of the electrical storage device in response to detecting a pulse of the radio frequency signal. When the discriminator detects the cardiac signal, a trigger signal is produced, which causes the pulse circuit to apply the stimulation voltage pulse across the pair of electrodes.

Brief Description of the Drawings

[0009] FIGURE 1 is a representation of a cardiac pacing apparatus attached to a medical patient;

[0010] FIGURE 2 is a circuit diagram of a power transmitter for the cardiac pacing apparatus;

[0011] FIGURE 3 is an isometric cut-away view of cardiac blood vessels in which a vascular electrode-stent and a second electrode have been implanted;

[0012] FIGURE 4 is a block diagram of an electrical circuit on the vascular electrode-stent shown in Figure 2; and

[0013] FIGURES 5 A, B, and C are waveform diagrams of three electrical signals in the cardiac pacing apparatus.

Detailed Description of the Invention

[0014] With initial reference to Figure 1, a pacing apparatus 10 for electrically stimulating a heart 12 to contract comprises a power transmitter 14 and a vascular electrode-stent 20. The power transmitter 14 preferably is worn outside the patient's body adjacent the chest and emits a radio frequency signal 16 which is received by the vascular electrode-stent 20. Alternatively, the power transmitter 14 may be implanted in the patient. As will be described in greater detail, receipt of radio frequency signal 16 provides electrical power for circuitry on the electrode-stent. The vascular electrode-stent 20 is placed in an artery or vein 18 which carries blood through the heart in close proximity to the sinus node. For example the vascular electrode-stent 20 may be positioned in the __________ artery.

[0015] Referring to Figure 2, the power transmitter 14 comprises a radio frequency (RF) transmitter 22 connected to a timing circuit 24 and to an antenna 26. Both the RF transmitter 22 and the timing circuit 24 are powered by a battery 28. The timing circuit 24 controls the RF transmitter 22 to emit periodic pulses of the radio frequency signal 16. For example, the pulses have relatively slow rising and falling edges, as shown in Figure 4A, so that the signal level gradually increases and decreases.

[0016] As illustrated in Figure 3, the electrode-stent 20 includes a body 30 similar to well-known expandable vascular stents that are employed to enlarge a restricted vein or artery. Such vascular stents have a generally tubular shape that initially is collapsed to a relatively small diameter enabling them to pass freely through blood vessels of a patient. The procedure for implanting the electrode-stent 20 is similar to that used for conventional vascular stents. For example, a balloon at the end of a standard catheter is inserted into the vascular electrode-stent 20 in a collapsed configuration. That assembly is inserted through an incision in a vein or artery near the skin of a patient and pushed through the vascular system to the appropriate location proximate to the sinus node of the heart 12. The balloon of the catheter then is inflated to expand the vascular electrode-stent 20, thereby slightly enlarging the blood vessel 18 which embeds the electrode-stent in the wall of the vein or artery. The balloon is deflated, the catheter is removed from the patient, and the incision is closed. Alternatively, a self-expanding stent may be utilized as the body 30. The slight enlargement of the blood vessel 18 and the tubular design of the stent's body 30 allows blood to flow relatively unimpeded through the vascular electrode-stent 20.

[0017] With reference to Figures 3 and 4, the vascular electrode-stent 20 has a pacing signal circuit 32 and a pickup device 34 in the form of a wire coil wound circumferentially around the body 30. A first electrode 36 in the form of a ring encircles the body. The pacing signal circuit 32 includes a pulse discriminator 38 connected to the pickup device 34. As will be described, the pulse discriminator 38 distinguishes between electrical pulses induced in the pickup device by electrical events at the sinus node of the heart and by the RF signal 16 from the power

transmitter 14. That distinguishing is based on the shape of the respective signal waveform and the pulses of those waveforms as illustrated in Figure 4A for the RF signal 16 and in Figure 4B for the cardiac signal from the sinus node. The RF signal has relatively long duration pulses with gradually rising and falling edges. In contrast, the electrical pulses of the cardiac signal are very short duration and rise and fall quickly. The pulse discriminator 38 also is able to detect when both types of pulses coincide in time.

[0018] Whenever an RF signal pulse is detected, the pulse discriminator 38 uses the energy of that signal to charge a storage capacitor 40 which supplies electrical power to the circuitry on the vascular electrode-stent 20. Other types of electrical storage devices may be employed. The radio frequency signal supplies power to the vascular electrode-stent, and unlike prior wireless pacemakers does not trigger cardiac stimulation.

[0019] The sinus node of the heart 12 emits an electrical cardiac signal which causes contraction of the heart chambers. The cardiac signal travels from cell to cell in paths through the heart to muscles which contract the atria. This signal also propagates along another path until reaching the atrioventricular (AV) node, which is a cluster of cells situated in the center of the heart between the atria and ventricles. The atrioventricular node serves as a gate that slows the electrical current before the cardiac signal is permitted to pass to the ventricles. This delay ensures that the atria have a chance to fully contract before the ventricles are stimulated.

[0020] Due to the placement of the vascular electrode-stent 20 in proximity to the sinus node, emission of the cardiac signal also induces an electric current pulse in the pickup device, or coil, 34 of the vascular electrode-stent 20, as depicted in Figure 4B. The pulse discriminator 38 recognizes the rapid rise time of this pulse as being produced by the cardiac signal, as compared to a RF signal pulse shown in Figure 4A. When a cardiac signal pulse is detected, the pulse discriminator 38 issues a trigger signal to a pulse circuit 42. The pulse circuit 42 is similar to circuits used in previous cardiac pacing devices which generate voltage pulses for stimulating a contraction of the heart, as shown in Figure 5C. Specifically, upon being triggered the pulse circuit 42 uses the charge on the capacitor 40 to produce a voltage pulse that is applied between the first electrode 36, that extends around the stent body, and a second electrode 44, which is remote from the vascular electrode-stent 20.

[0021] As shown in Figure 3, the second electrode 44 is secured to the wall of a blood vessel 46 in another section of the heart and is connected to the pulse circuit 42 by a thin insulated wire 48 extending through the blood vessels. The relatively small size of the second electrode 44 allows it to be placed into a significantly smaller blood vessel 46 than the vascular electrode-stent 20. As a result, the second electrode 44 can be placed is a greater variety of locations in the cardiac vascular system and in close proximity to the muscles that contract the desired portion of the heart 12.

[0022] Depending upon whether the second electrode 44 is placed to stimulate contraction of an atrium or a ventricle, the pulse circuit 42 delays a predefined amount of time after receiving the trigger signal from the pulse discriminator 38 before applying the voltage pulse to the first and second electrodes. Therefore, timing of muscle

stimulation corresponds to that which occurs with respect to naturally induced contraction of the atrium or ventricle. The duration of that delay is programmed into the pulse circuit 42 by the surgeon upon implantation and is a function of the location of the second electrode.

[0023] In another version of the vascular electrode-stent 20, one or more additional electrodes, such as a third electrode 50, can be implanted in other cardiac blood vessels 52 to stimulate further sections of the heart. In this case, individual voltage pulses can be applied between the first electrode 36 and each of the additional electrodes 44 and 50 to separately stimulate contraction of those other sections of the heart. A stimulation pulse also may be applied between the second and third electrodes 44 and 50, without using the first electrode 36.

[0024] The foregoing description was primarily directed to preferred embodiments of the invention. Even though some attention was given to various alternatives within the scope of the invention, it is anticipated that one skilled in the art will likely realize additional alternatives that are now apparent from disclosure of embodiments of the invention. Accordingly, the scope of the invention should be determined from the following claims and not limited by the above disclosure.